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DETECTION OF UPWARD LIGHTNING FROM TOWERS IN SÃO PAULO, BRAZIL BY LIGHTNING LOCATION SYSTEMS

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We report upward lightning observations in São Paulo city, SP, Brazil and compare to data from Lightning Location System (LLS). Those data were provided by 4 different networks from different technologies: BrasilDAT, RINDAT, Worldwide Lightning Location Network (WWLLN), and Earth Networks Global Lightning Network (ENGLN). Several upward flashes were observed from 2012–2014 using GPS time-stamped optical sensors and electric field measurements. These upward flashes were initiated from tall towers located at Jaragua Peak (90 and 130 m) and along Paulista Avenue (23 towers with heights between 50 and 220m). Time-correlated analyzes allowed to evaluate the network detection efficiency, intracloud (IC) / cloud-to-ground (CG) misclassification percentage, and location accuracy of the 4 different LLS. We will also show how different upward flash physical processes (leader initiation, recoil leaders, return strokes) are detected and classified by the distinct LLS technologies. Preliminary results show that in general, recoil leaders were not detected; on the other hand, several cases of return strokes and some cases of M-component were detected by one or more LLS networks.

Fig 1 - High resolution photo of a registered upward lightning in Jaragua Peak

1 - INTRODUCTION

Recorded in January 2012 for the first time in Brazil, upward flashes are lightning discharges that initiate from tall structures like communication towers, skyscrapers or wind turbine generators. When a thunderstorm approaches a tall structure, the electric field becomes so intense that favors the initiation of upward leaders that propagate towards the cloud base [1]. The leader propagation provides the inception of an electric current that will flow through the tip of the tower to the ground. This current may last several hundred milliseconds and is named initial continuous current (ICC).
The ICC may fluctuate and contain current pulses named ICC pulses. After the cessation of the ICC, downward leaders may arise, which may produce subsequent return strokes, followed or not by a continuing current. Fuchs et al. (1998) reported peak currents of about 3.9 kA for ICC pulses and 8.5 kA for the return strokes [2].

The detection system of atmospheric discharges, which constitutes a measuring instrument to detect cloud-to-ground (CG) or intra-cloud (IN) lightning, is based on networks of remote sensors that are capable of detecting electromagnetic radiation emitted by lightning [3]. They measure some characteristics that will describe the event, such as the intensity of the peak current, multiplicity and polarity [4].
In this article we will use the networks of BrasilDAT, RINDAT, Worldwide Lightning Location Network (WWLLN), and Earth Networks Global Lightning Network (ENGLN) in order to identify which processes of lightning seen by high-resolution cameras and the field sensor electric, were detected.

2- INSTRUMENTATION AND METHODOLOGY

Using high-speed cameras, we report observations of upward lightning from towers located in the city of São Paulo, SP, Brazil, and compare this data to those obtained by Lightning Location System (LLS) and fast electric field.

The observed upward lightning flashes started from towers 70-130 meters, located in Jaragua Peak and about 23 towers along the Paulista Avenue, which heights vary between 50 and 220 meters.
In Figure 2, the squares marked in red are towers along Paulista Avenue and the towers of Jaragua Peak. The the black circles in Figure 2 are observation points used by the cameras (4,000-20,000 frames per second) facing the towers.

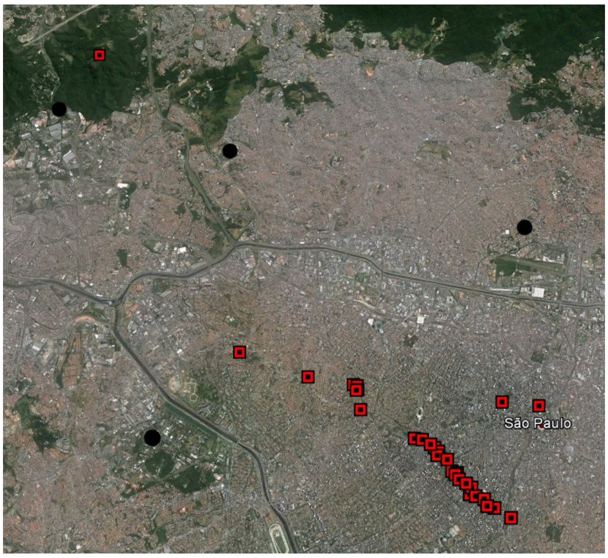

Fig. 2 - Local instrumentation (red square) and locations of towers observed (black circle)

High-speed videos

The use of high-speed videos allows us visualize every stage of the upward flash: the ICC, the ICC pulses, the no current interval and the return strokes. If the channel of the lightning discharge is luminous, we assume that some current is flowing.
In this study we will present a case of an upward flash that occurred on March 27, 2012. This case presented ICC pulses and subsequent return strokes.

Figure 3 shows an example of an ICC pulse registerd by the high-speed video at 10,000 images per second. The recoil leader occurs when some luminosity is still presente.

Fig. 3 - Registration ICC pulses

The Figure 4 shows that after cessation of the ICC, a downward leader appears following the same previous channel, resulting in a subsequent return stroke.

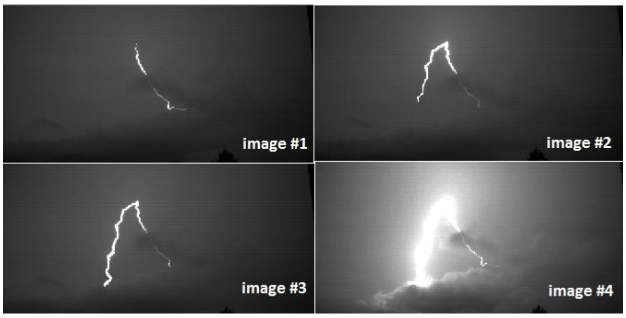

Fig. 4 - Registration SRS

LLS Data

The LLS data were filtered so that only discharges within a 100km-radius circle around the Jaragua Peak were analyzed. The data provide the location and time of each discharge occurred.

Eletric field

The electric field measuring system consisted of a flat plate antenna with an integrator/amplifier, a GPS receiver, and a PC with two PCI-cards (a GPS card Meinberg GPS168PCI and a data acquisition card NI PCI-6110), and a data acquisition box (DAQ BOX NI BNC-2110). The waveform recording system was configured to operate at a sampling rate of 5 MS/s on each channel and the resolution of the A/D converter is 12 bits. The same type of measuring system has been used previously in lightning experiments in Austria and Sweden and is described in more detail by Schulz et al. [2005].

Figure 5 – Electric field system.

The electric field was used to check the characteristics of the events that were detected and of those not detected.

An example of electric field measurement is shown in Figure 6. It shows the signature of the positive cloud-to-ground flash that preceded the upward flash on March 27, 2012 at the Jaragua Peak. At the end of the record it is possible to see the signature of the ICC pulses and return strokes (illustrated also in Figure 7).

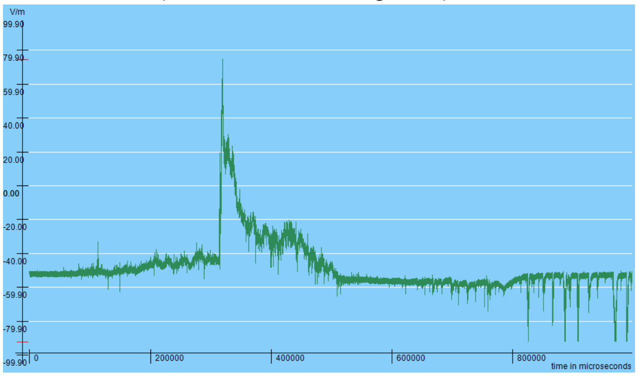

Fig. 6 - Example of the electric field of an upward lightning

3 – RESULTS

Figure 7 shows the signature of the ICC pulses and return strokes that appear in Figure 6. Each pulse was numbered, classified using the images of the high-speed video and then using data from BrasilDat, RINDAT, WWLN and ENGLN networks we checked if they were detected or not.

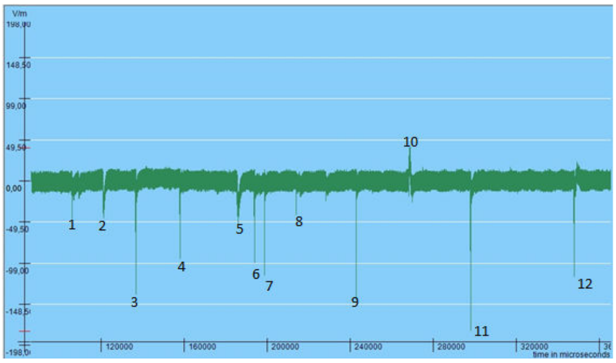

Fig. 7 - Image of the electric field of an upward lightning

Table 1 presents a summary of characteristics of each pulse and if detected, the attributed peak current. The characteristcs are: E-field peak amplitude (V / m); 10 and 90% risetime (μs) and peak-to-zero (PTZ) (μs).

Out of 12 pulses that were registered by the electric field sensor, 3 were not associated to any brightness in the video record. Out of the remaining 9 pulses (associated to events on the video) 5 were detected by BrasilDat, 4 detected by RINDAT and none detected by WWLN or Starnet. All detected events were classified as cloud-to-ground discharges, except the one highlighted in bold in Table 1, which was classified as an intra-cloud discharge.

The PTZ and risetime of all pulses were approximately the same (ranging from 1 to 2 microsseconds). ICC pulses with electric-field peak amplitude less than 90 V/m were not detected by any LLS. The peak current estimated by RINDAT was much higher than the values estimated by BrasilDAT.

Recoil leaders that did not reach the tower were not detected by any of the networks. Pulse 12, a return stroke, was also not detected.

Physical Processes	1	3	4	6	7	8	9	11	12
	ICC pulses	ICC pulses	ICC pulses	ICC pulses	ICC pulses	ICC pulses	ICC pulses	ICC pulses	SRS
Ep(V/m)	-45	-134	-91	-96	-111	-40	-140	-176	-113
Risetime (μs)	1,8	1,4	1,2	1,4	1,2	1,2	1,0	1,2	1,0
PTZ (μs)	2,0	1,8	2,0	1,2	1,2	1,2	1,2	1,6	1,2
BrasilDat (kA)	-	-	**-7**	-9	-9	-	-12	-16	-
Rindat (kA)	-	-20	-	-14	-	-	-23	-25	-
WWLN	-	-	-	-	-	-	-	-	-
ENGLN	-	-	-	-	-	-	-	-	-

Table 1 – Characteristics of the ICC pulses and detection.

4 - CONCLUSIONS

In this work, we studied the characteristics and detection of an upward lightning flash. We analyzed the video and the electric field measurement in order to compare it with the data from the Lightning Location Systems (LLS) BrasilDat, RINDAT, WWLN and ENGLN.
Our analysis shows that recoil leaders that not reached the tower were not detected by any of the networks. Only ICC pulses were detected.
All pulses but one were correctly detected as cloud-to-ground.
We are now making a similar analysis for the complete dataset of 80 upward flashes.

5 - REFERENCES

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